

Searching For Dark Matter With PICASSO

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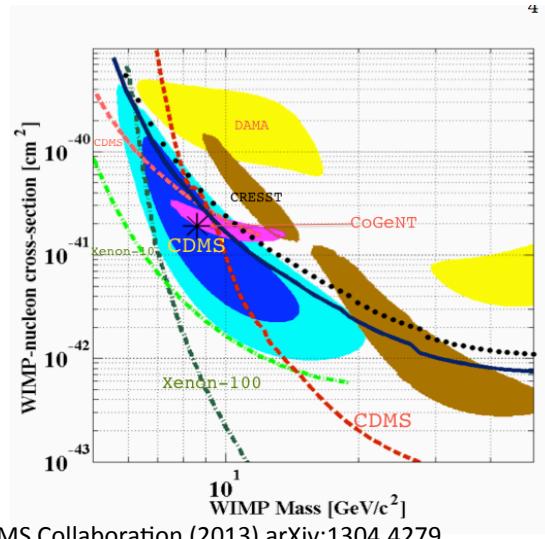
On behalf of the PICASSO Collaboration

9th Sep 2013

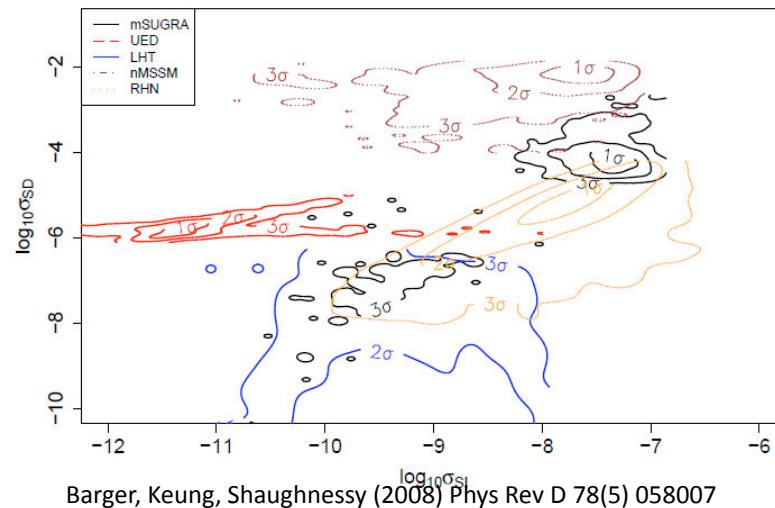
13th International Conference on Topics in
Astroparticle and Underground Physics (TAUP)

PICASSO

- Project In CANada Searching for Supersymmetric Objects.
- Operating detector in SNOLAB, Sudbury, Ontario, Canada
- Members from Canada, Czech Republic, India and USA.
- A superheated liquid detector using C_4F_{10} target.



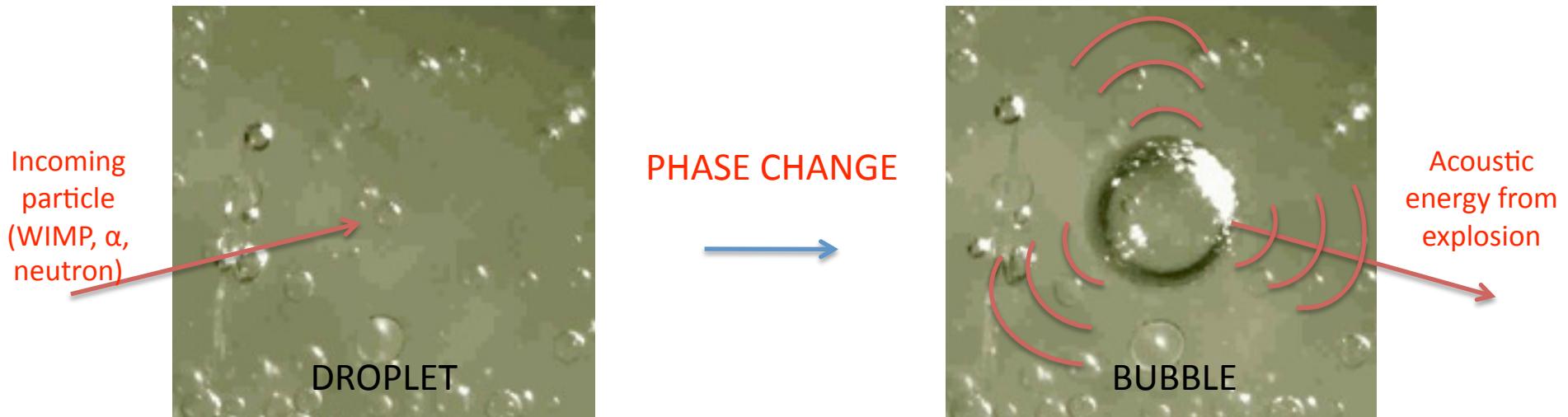
Operates at low threshold allowing investigation of low mass WIMPs.



Target of ^{19}F most favourable for spin dependent interactions due to spin enhancement factor.

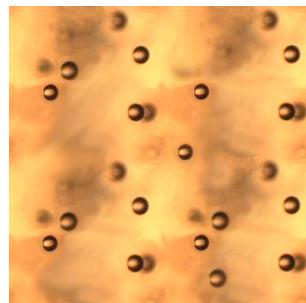
Operation Principle

- A **superheated liquid detector** based on bubble chamber principle.
 - (F.Seitz, Phys Fluid I (1)(1958)2).
- If sufficient **energy** (E_{\min}) is deposited within **radius** (R_{\min})
 - where $R_{\min}, E_{\min} \propto$ temperature dependent superheat, surface tension and critical length and energy efficiency factors.
- from, eg **nuclear recoil** or **alpha bragg peak**,
- a **bubble** forms.
- The **explosion** can be measured **acoustically**.
- A **threshold** detector. Dependent on **temperature**.

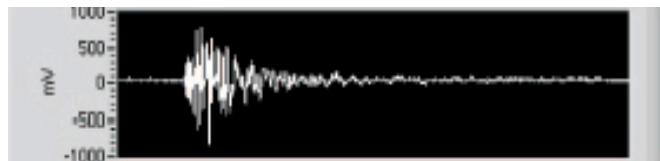


The Detector

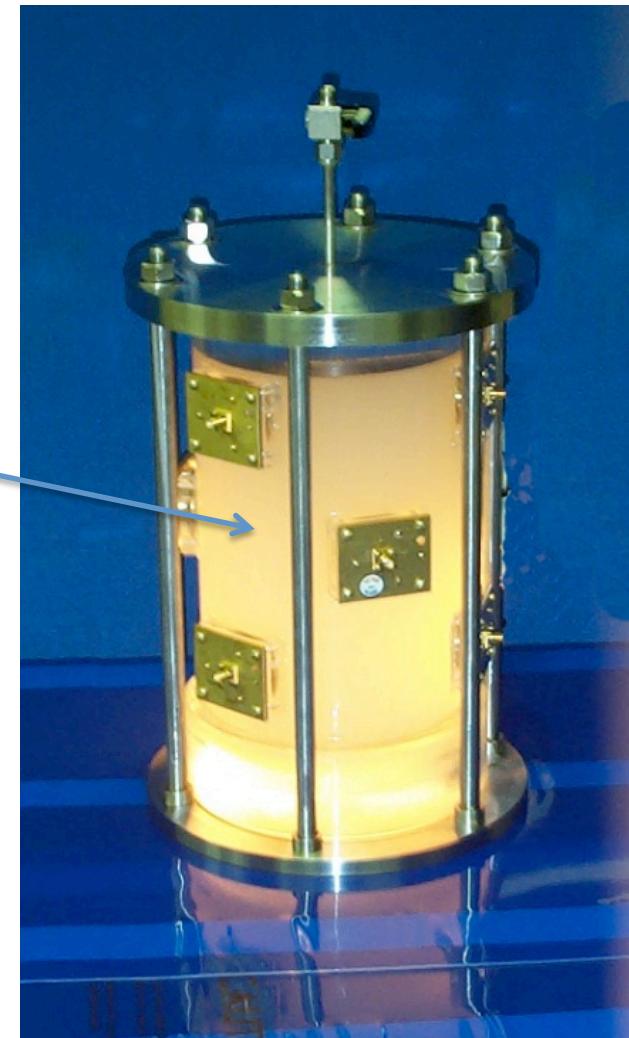
- Modular detector (**32 modules**).
- Uses **C₄F₁₀ droplets** (~200 µm diameter)...
- ...suspended in **polymerised aqueous gel matrix**...



- ...in 4.5L acrylic cylindrical container.
- 9 piezoelectric **transducers** record sound.



- 40-50 hr **data taking runs**.
- 2-5 hr **calibration** runs with **neutron source**.
- 11 hr **recompression** between runs.



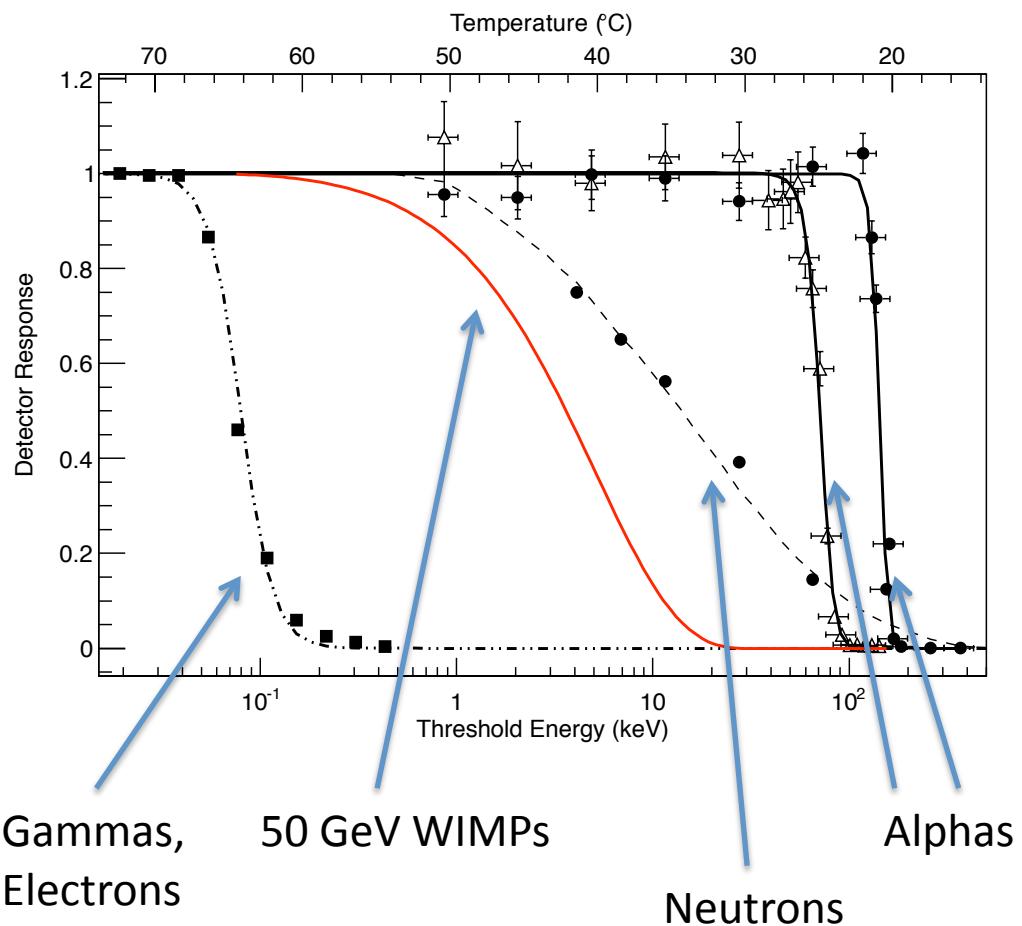
The Detector



- Detectors in temperature and pressure control system.
- Enclosed within **water shielding** in SNOLAB.



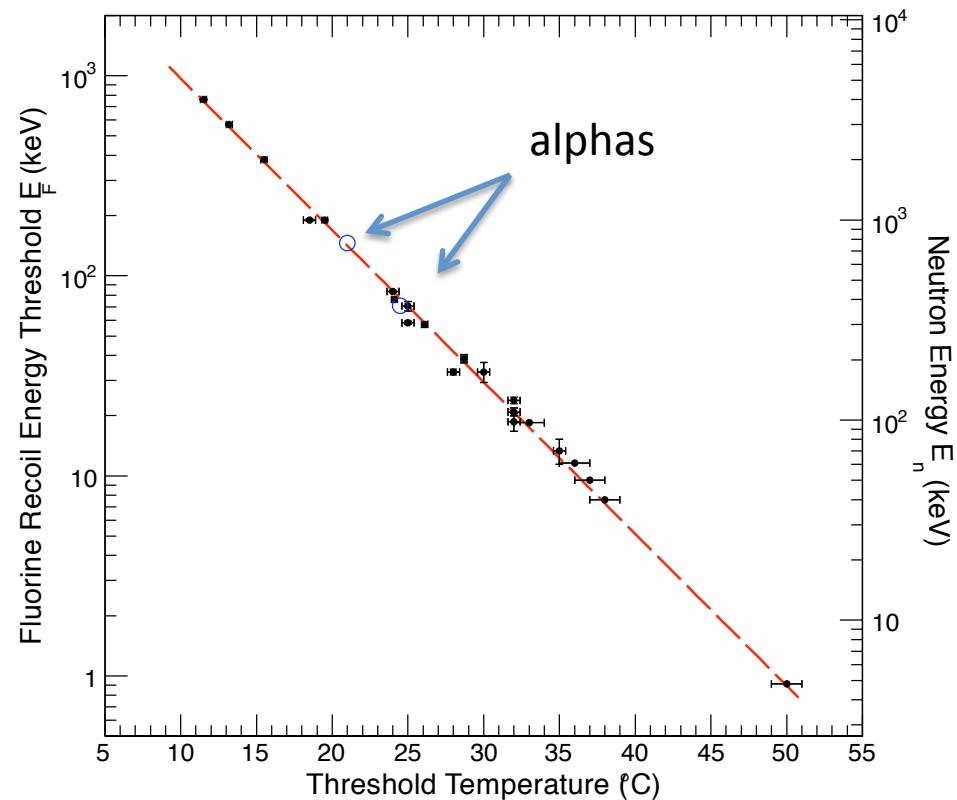
Detector Response



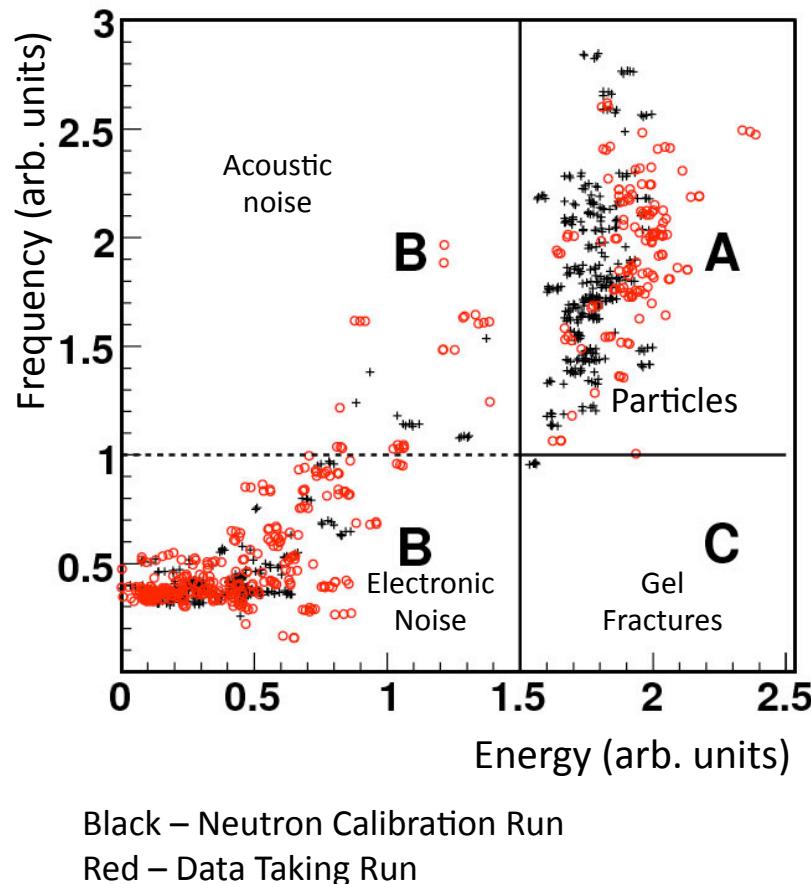
- At PICASSO operating temperatures ($< 50^\circ\text{C}$) **gammas and electrons suppressed by 8 orders of magnitude.**
- **Neutrons** background controlled by underground lab, water **shielding**.
- **Alpha particle main background.**

Energy Threshold

- Calibrations with mono-energetic neutron beam of energy threshold to **0.86 keV**.
- Alpha measurements **consistent** with calibration.
- Alphas above threshold **fully efficient**.
- More **low threshold** measurements underway.



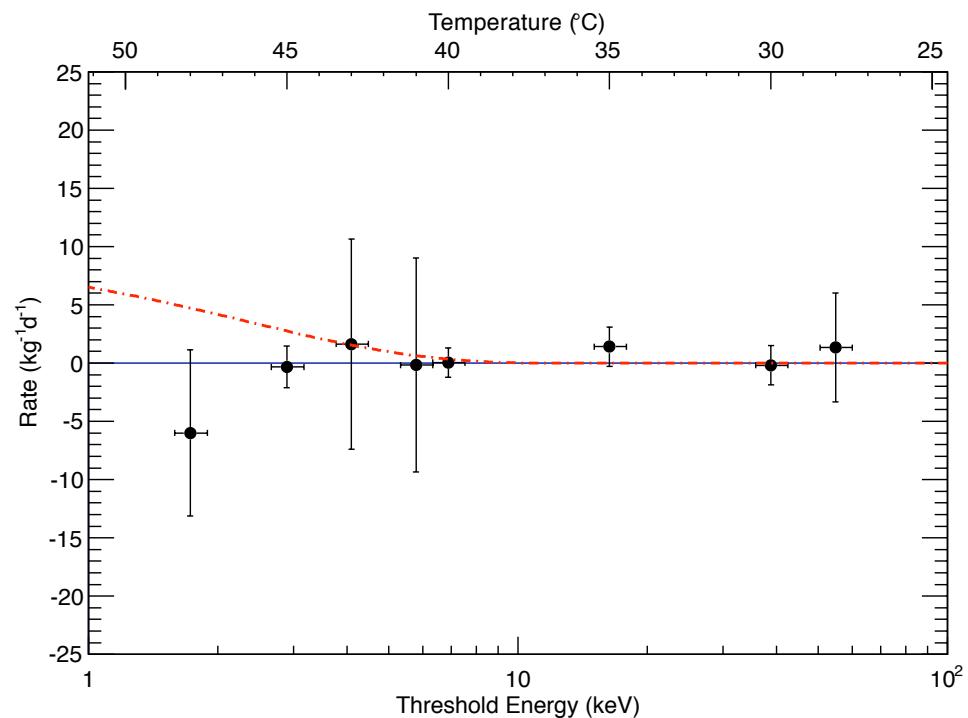
Event Selections



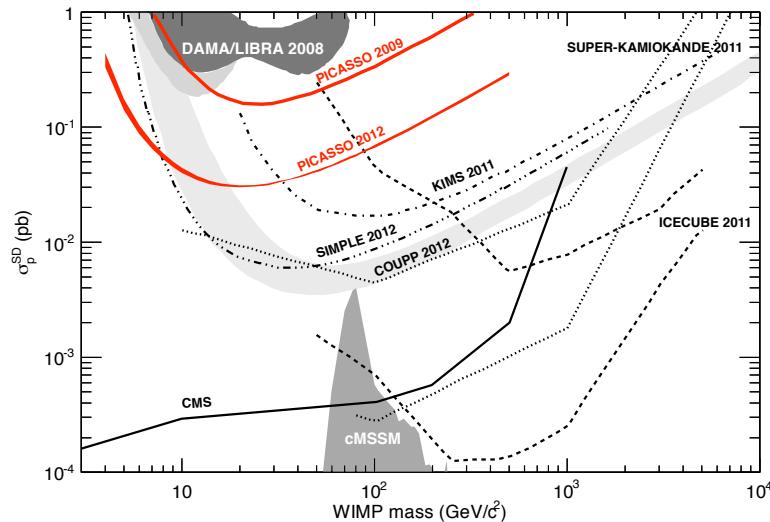
- The **acoustic signal** from bubble formation recorded and used in analysis.
- Events are selected using:
 - Acoustic **energy**
 - **Frequency**
 - Signal **rise time**
 - Correlation with other events in time (**burst cut**)

Event Rate

- Event rate of 10 PICASSO detectors for spectrum of temperatures.
- Flat alpha background (subtracted for clarity).
- Example WIMP of $M_w = 7 \text{ GeV}/c^2$, $\sigma_{SI} = 1.2 \times 10^{-4} \text{ pb}$, $\sigma_{SD} = 5.0 \times 10^{-3} \text{ pb}$.

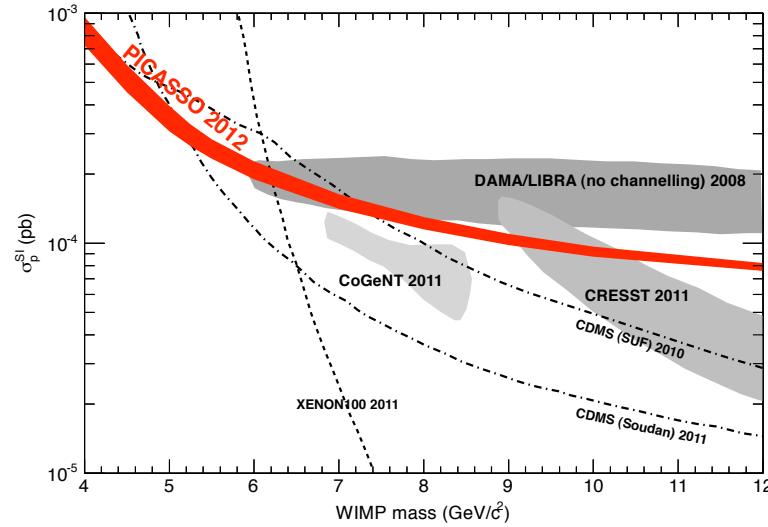


Dark Matter Limits



Spin Dependent

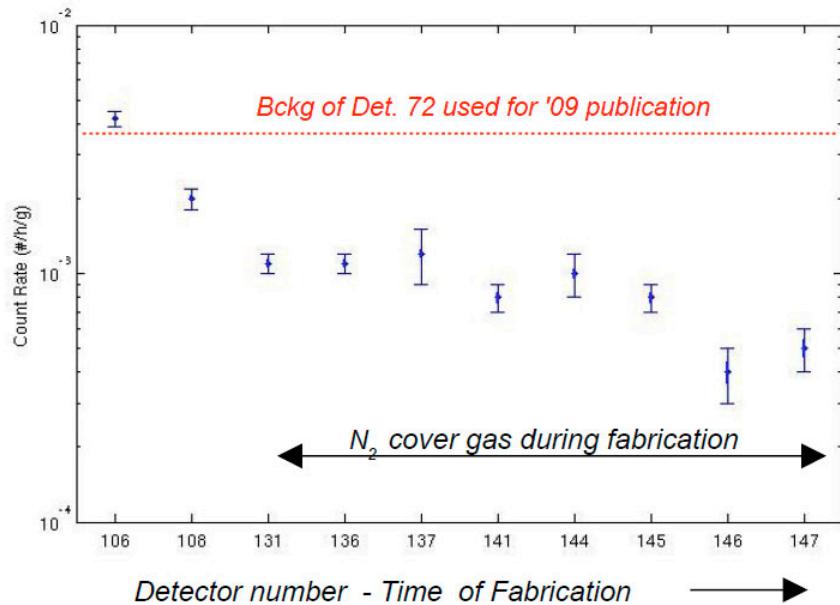
- Most recent results from 2012 (Archambault et. al. Phys Lett B 711(2) (153-161)).
- Best SD exclusion $M_W = 20 \text{ GeV}$, $\sigma_p = 0.032 \text{ pb}$ (90%CL).
- 114 kgd exposure (10 modules, 0.72 kg of ^{19}F).
- Improvement by factor 5 on previous results.
- Results exclude DAMA/LIBRA (with channelling) in SD sector.
- Interesting in SI region.
- Improved limits from COUPP and others subsequently published.



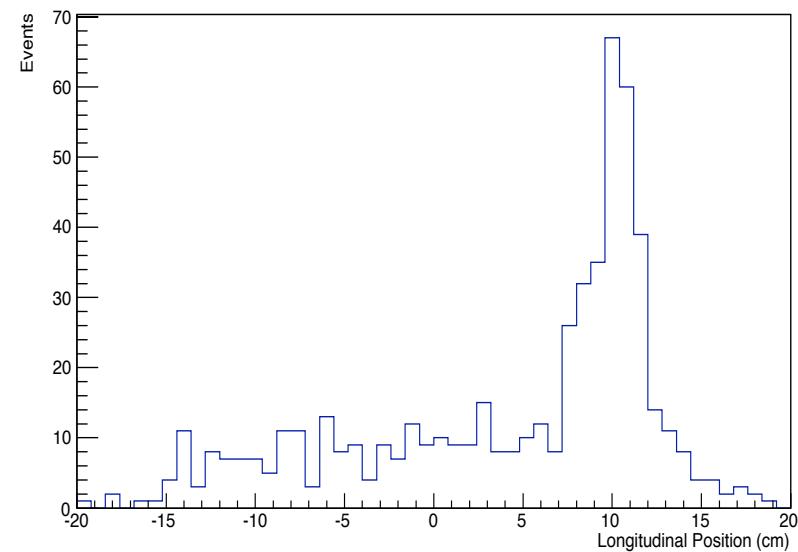
Spin Independent

PICASSO Forthcoming Results

- New results in preparation for publication soon.
- 12 low rate detectors with additional exposure of ~ 250 kgd.



Improved radiopurity.

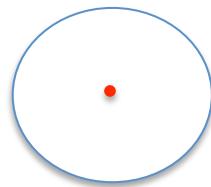
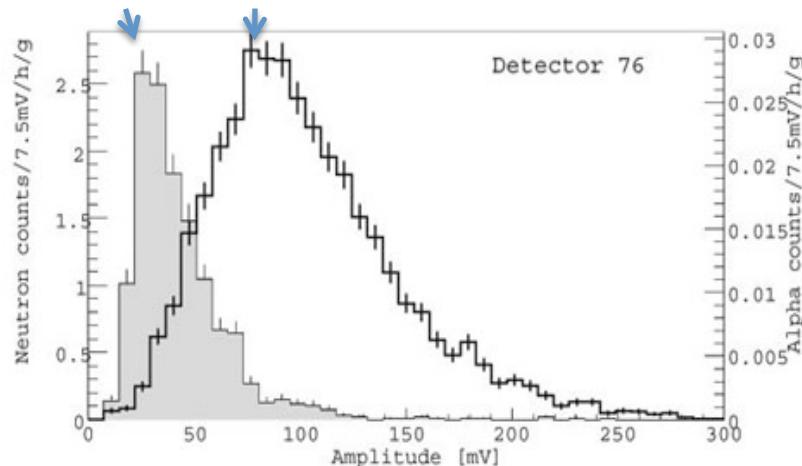


New event localisation to remove background hotspots.

- By completion (end of 2013) ~ 800 kgd exposure with 32 detectors expected.
- Expected limits of $\sigma \approx 0.007$ pb with current analysis.

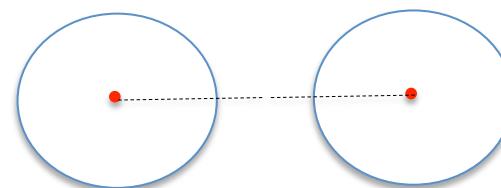
Alpha – Neutron Discrimination

neutron alpha



Nuclear recoils have
point-like bubble
nucleation.

- Discovery of **alpha-neutron discrimination** using acoustic signal (New Jour. Phys. 10 (2008) 103087).
- Alphas are **louder** than neutrons.
- **Confirmed** by COUPP.



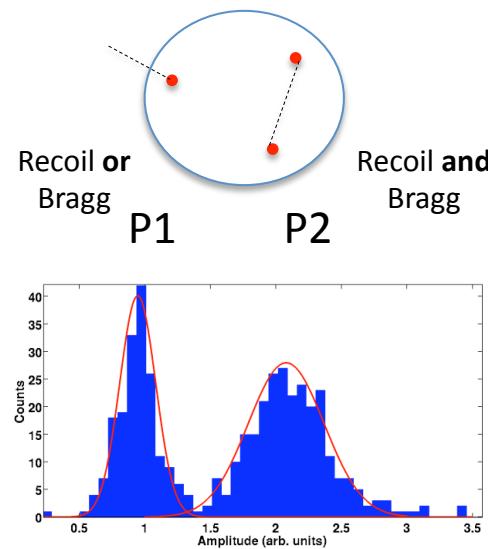
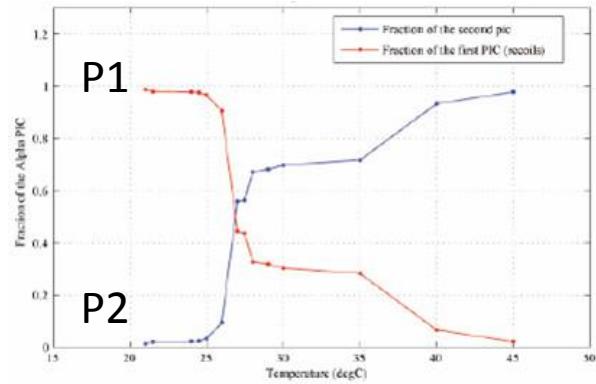
Alpha particles have track-like
bubble nucleation due to
nuclear recoil and Bragg peak.

Number of nucleation sites influences resultant signal.

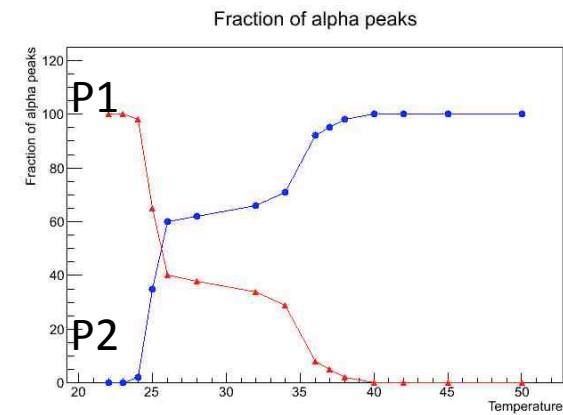
Alpha – Neutron Discrimination

- Complicated to discriminate in droplet detectors.
- Depends on origin of alpha particle (inside or outside droplet), size of droplet and temperature.

Data:



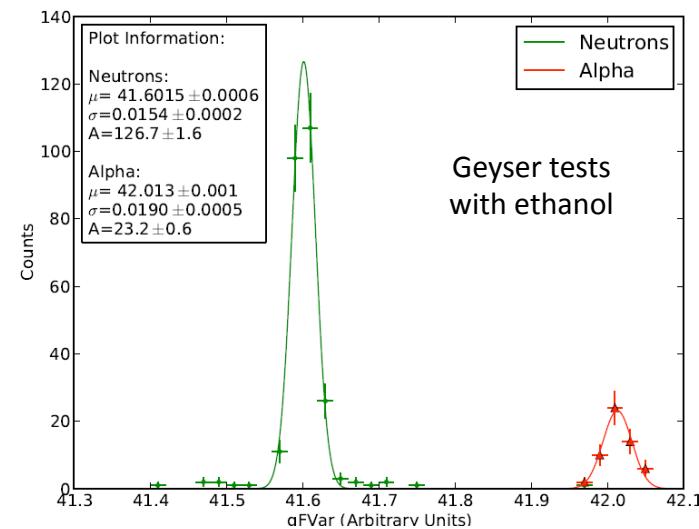
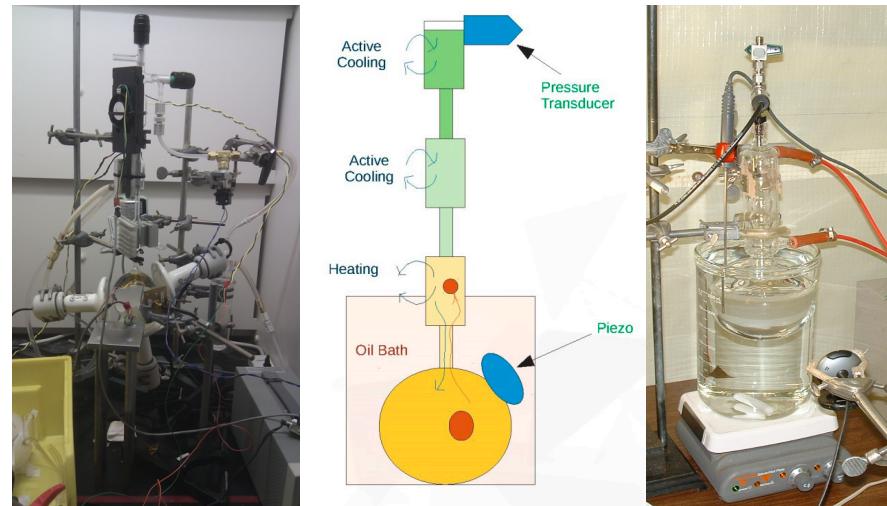
Monte Carlo:



- Ongoing work to improve resolution and discrimination in PICASSO.
- Localisation for distance and angle resolution corrections, fiducial volume selections, wavelet analysis, pulser for gain stability corrections, double speed electronics, gain optimisation of electronics, new variables based on event shape...
- Expect ~factor 3 improvement in limits with respect to standard analysis if possible.

Research and Development

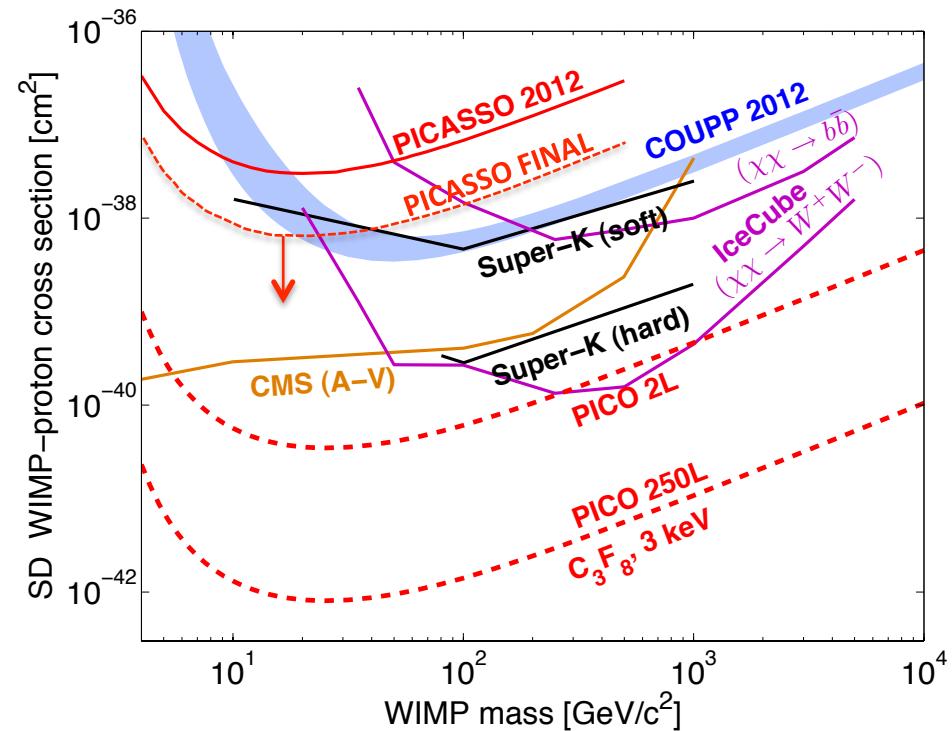
- Large detector R+D **underway** to build 100 kg detector.
- Alternative technique using **condensation chamber** (geyser).
- Condenser above chamber to cool and **condense bubbles automatically**.
- Minimises detector **deadtime**.
- Uses **bulk liquid** so droplet edge effects unimportant.
- **Full discrimination** possible.





PICO

- The PICASSO and COUPP collaborations have joined to explore **large scale** superheated detector options as **PICO**.
- PICO-lite**
 - 2L C_3F_8 chamber using COUPP **compression chamber** technology.
 - Low energy threshold** and excellent **alpha discrimination**.
 - Large sensitivity in **spin dependent** sector.
 - Starts running **Fall 2013**.
 - See talk by Russell Neilson.
- PICO 250L**
 - Large detector **research and development**.
 - Choice of **compression chamber** or **geyser** technology.



Conclusions

- ^{19}F target useful for exploration of spin dependent dark matter interactions at very low energy thresholds.
- Use superheated liquid technique allows very low background detectors (only alphas and neutrons).
- PICASSO has made leading limits in SD dark matter searches, and probes interesting SI physics results.
- Possibility of alpha discrimination using acoustic energy.
- Publication of new results soon.
- Large scale detector research and development underway with PICO.